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BIRDS IN FLIGHT AND THE FLYING MACHINE.

BY HIRAM S. MAXIM.

THE ease with which birds can move from place to place has always excited the envy of mankind, and from the days of Icarus and Daedalus down to the present day, philosophers and mathematicians have tried to solve the secret of a bird's flight.

It has been asserted by many mathematicians, that if a bird should be considered as a machine, it would be quite impossible for it to fly, according to the accepted laws of aëro-dynamics.

When Professor Darwin was in South America many years ago he was unable to account for the flight of the condor. He speaks of seeing condors circling about in a valley, rising higher and higher without any perceptible motion of their wings.

Professor Proctor, the astronomer, while on a visit to Florida, studied the flight of turkey buzzards. He observed that they were able to soar quite independent of any motion of their wings. They seemed to balance themselves on the air and move forward, and sometimes upward, without the expenditure of any force at all. He attempted to account for this on the hypothesis that as they were moving forward at a very high velocity they did not rest on the same air long enough for the air to be set in motion.

Professor Froude, the mathematician, while making a voyage in the South Atlantic, observed the flight of that greatest of all flyers, the albatross, and he admitted that no existing mathematical formula could account for the soaring of these birds without any apparent movement of their wings.

A great many others have written learned treatises on the soaring of birds, but, as far as I know, nothing has yet been published which is altogether satisfactory. Some years ago, while in Spain, I observed the flight of a pair of very large eagles. They came into sight on one side of a large and level plain, crossed it almost in a straight line and disappeared without a single apparent motion of their outstretched wings.

I also saw eagles soaring in the Pyrenees in the same way.

I have crossed the Atlantic many times, and have studied the flight of sea-gulls. Some of these birds are able to follow the ship for days at a time, and it is no uncommon thing for a gull to maintain a fixed position in the air as relates to the ship without any apparent exertion at all, and to follow the ship exactly as it would do if it were secured to it with a cord.

All these phenomena seem quite inexplicable if we consider them on the basis that the birds are moving in stationary air. Some mathematicians of the lesser order who only partly understand the question, have supposed that a bird is able to maintain itself on a horizontal current of air, that is, a wind blowing in a horizontal direction, but this would in no way account for the phenomenon, because if a bird should hold itself in a stationary position against a wind that was blowing 25 miles an hour, the conditions would be identical with those which would obtain if the bird were moving forward at the same velocity through stationary air, and we should be quite as unable to account for the soaring in one case as in the other.

Some years ago I passed a winter on the shores of the Mediterranean in the south of France, where I had a good opportunity of observing the mistral and also air currents over the bays in the south of France. I have since made two trips through the entire length of the Mediterranean, and have observed that the winds do not blow in a horizontal direction at all, but that even in what we call a dead calm there are always vertical currents. Sometimes with the ship sailing in a very nearly calm sea, ripples appeared on the water, showing that there was a direct though very slight head wind. I observed that these ripples became less and less as the ship moved onward, until they completely disappeared in a glassy streak, 300 or 400 feet wide and which extended on either side of the ship in nearly a straight line as far as the eye could reach. As soon as this glassy streak was passed I observed that the wind was blowing in the opposite direction, that is, with the ship; and then, perhaps a mile or two ahead, we would find another glassy streak towards which the wind was blowing from both sides. Over the first of these streaks the air was of course descending, and over the other, ascending.

At Monte Carlo I obtained photographs of the surface of the Mediterranean from the Tête de Chien, which is 2,000 feet above the sea. These photographs show the whole surface of the sea to be streaked like marble. Each glassy streak represents a neutral zone where the air is either ascending or descending, while the water which appears of a darker color in the photograph is covered with small ripples, and on all occasions I observed that the ripples on one side of the glassy zone were travelling in exactly the opposite direction to those on the other side.

Through the whole of the south of France we hear much of the mistral, or a cold, vertical wind. One may be out driving, the weather may be soft and balmy, when suddenly the carriage enters a chilly zone. The air is travelling downwards, spreading itself out over the surface of the earth, becoming warmed, and ascending at some other point. The cause of these vertical currents is, of course, the same as the cause of all winds. The rays from the sun passing through the highly attenuated upper stratum of the atmosphere do not encounter sufficient resistance to communicate any perceptible heat to the air, but the denser air near the surface of the earth becomes heated by contact with the relatively warm earth. We often have, while the sun is shining, a layer of cold air superposed on a layer of hot air. Now as hot air has a less specific gravity at the same pressure than cold air, it follows that these two layers of air are constantly changing places, the relatively warm air at the surface of the earth ascending, expanding, doing work and becoming cooled, while the cold air from above settles to the earth to take the place of the warm air. The velocity with which these vertical currents move is, say, from one mile to six miles an hour, and their movement is quite independent of any other horizontal current that the air may have as relates to the earth at the same time. These currents may be going on in a valley surrounded by mountains without any other action of the atmosphere. On a plain, however, there is also another action taking place at the same time, but which does not in the least interfere with the vertical action, that is, the whole body of air may be passing along over the surface of the earth at the rate, we will say, of 10 miles an hour, while the vertical action is going on at a velocity of, say, four miles an hour. The soaring of a bird may be compared with a boy sliding downhill on a sled. If a hill is, say, 100 feet high, and the sides slope off in a horizontal direction 2,000 feet from the summit, and if the snow is smooth, a boy can mount a sled and advance 2,000 feet while he is falling, as relates to the earth, 100 feet; that is, the sled with the boy on it in falling through a distance of one foot develops sufficient power to drive the sled forward twenty feet, but when the boy is at the bottom of the hill and can develop no more power by falling, the sled soon comes to a state of rest. Suppose now that a hill could be made in such a manner that it would constantly rise at such a velocity that the sled would never reach the bottom of the hill, the boy would then be able to slide forever, and this is exactly what occurs with a bird. A bird places its wings in such a position that, as it falls in the air say one foot, it moves forward through the air twenty feet, that is, it slides along on the surface of the air underneath its wings in the same manner that the boy slides down the hill. Suppose now that the velocity of the bird should be about thirty miles an hour, this would account for the whole phenomenon of soaring on an upward current of only one and one-half miles an hour. With an upward current of two miles an hour, the bird would rise, as relates to the earth, one-half a mile an hour while actually falling through the air at the rate of one and one-half miles an hour. There is no doubt that a bird, by some very delicate sense of feeling and touch, is able to ascertain whether it is falling or rising in the air. It is well known that fish have this power. If a surface fish sinks too deeply in the water the compression of its swim bladder produces a sensation or impression upon its brain, which causes the fish to change its course, and relieves the pressure by coming nearer to the surface, and a similar thing is true of the deep sea fish. If they approach the surface their swim bladder becomes enormously distended and no doubt produces a sensation which the fish know is relieved by again sinking into very deep water. If these fish are caught and drawn to the surface, the distension of the swim bladder becomes so great that it displaces all the other organs of the body. In all probability the numerous air cells which are found in the body of a bird are provided with delicate nerves, which operate in a similar manner to those of the swim bladder of a fish, so that as the bird is moving forward through the air it is able to take advantage of a rising column of air. As a whole we may consider that the rising columns of air would be half of the total area of the earth's surface, so that a soaring bird would always have a rising column of air which would serve as a support.

Referring to the eagles which I saw in the Pyrenees, on one occasion I observed five of these birds about 500 feet above the peak of a mountain and they were balancing themselves in a stationary position on an ascending column of air produced by the wind blowing over the peak, and seemed to be as much at ease as if they were roosting upon a tree. With the albatross and seagull it will be found that they always occupy the same position as relates to the ship. As the ship passes through the air, the air is divided exactly in the same manner as water would be, and as it comes together again at the stern of the ship it produces an upward current, and it is on this ascending column of air that the albatross and the seagull find a resting place and follow the ship for days at a time without any apparent exertion ; but whenever they find themselves in front of the ship or at one side where there is no ascending column of air they have often to work their passage very much as other birds do.

But all birds do not soar. Ducks, geese, partridges and pheasants are types of birds which are provided with comparatively small wings. They only remain on the wing for a short time and while in the air exert an enormous amount of energy and move at a very high velocity. They do not seem to have the power to take advantage of ascending columns of air, but move in a straight line quite independent of air currents, and it is these birds we should seek to imitate in our attempts to navigate the air.

The experiments of Herr Lilienthal are very interesting. He has provided himself with a large pair of wings and a tail. He mounts a high hill and while the wind is blowing up the side of the hill, he throws himself forward with great force against the air and slides down on the ascending column very much as a boy would slide down hill on a sled, his flight being exactly like that of a flying squirrel. The power which drives him onward is of course generated by the act of taking himself and the machine to the top of the hill exactly the same as is the case with the boy and the sled. Lilienthal has certainly proved that it is possible for a man to balance himself in the air, and this at least is a solution of one part of the problem of flight.

Professor Langley has lately made some small flying machines weighing a few pounds which are said to fly a few hundred feet.

Hargraves has also made some small machines weighing a few ounces which are said to fly some two or three hundred feet.

Mr. Phillips, a clever engineer living near London, made a small flying machine some years ago which rested on three wheels and was driven by a steam engine. By bottling up his steam and expending all that he had made in twelve minutes in about half a minute, he was able to drive his machine at a sufficient velocity round a circular track to lift two of the three wheels clear of the track.

My own experiments have been made on a very much larger scale than any heretofore conducted. It appeared to me that all other experimenters had made their apparatus so small as not to be able to get a large amount of power out of a small weight of material. My large machine may be considered as a very large and perfectly made kite, the framework consisting of very light and strong steel tubes and covered top and bottom with balloon cloth, waterproofed, and made very sharp fore and aft. To the sides of this framework wings are attached which are also nothing more nor less than kites. If my large machine should be taken on to a level plain and be anchored to the ground, it would weigh about 8,000 lbs. in a calm, but if the wind were blowing at the rate of forty miles an hour, its weight would be *nil*, while if the wind should be blowing at forty-five miles an hour, it would raise the whole machine and 2,000 lbs. additional weight besides into the air after the manner of a kite. But a wind of forty-five miles an hour does not often occur and cannot of course be depended upon, so I have provided myself with a railway track 600 yards in length. If my machine is run into the air at a velocity of forty-five miles an hour, the result is the same as it would be if the machine were stationary and the wind was blowing at this velocity. Instead of the anchor rope for pulling the machine into the air, I use a pair of very large and well made screw propellers, each driven by a very powerful and light steam engine, and when these engines are running at a steam pressure of 310 lbs. to the square inch, they develop 360 H. P., and produce a thrust on the machine of 2,200 lbs. If the machine were flown like a kite in the air, in a wind blowing at forty-five miles an hour, the strain on the cord which held it against the wind would be 2,200 lbs. Consequently when my screws push the machine forward with a total thrust of 2,000 lbs. in a calm air, the machine moves forward at forty-five miles an hour and the lifting effect equals the weight of the machine and 2,000 lbs. besides. If I only had an ordinary railway track, some of the wheels of the machine would be sure to leave the track before I had attained a speed of anything like forty miles an hour, so that if I wish to lift all the wheels off the track and not have the machine become unmanageable, it is necessary that I should have something to hold the machine down, and this is accomplished by providing an inverted secondary track just outside and above the ordinary railway track. Outriggers attached to the sides of the machine are provided with four wheels which engage the underneath side of this upper track whenever the machine is lifted clear of the ordinary track. In this way I am able to run my machine to show its lifting effect and still not allow it to get off the track and become unmanageable. In the park where my experiments have been conducted there is barely room for the machine to pass between the large trees, so that manœuvring near the ground is quite out of the question. I have, however, proved that it is possible to make a machine that has sufficient power to lift itself into the air without the agency of a balloon, so it now only remains that I should obtain very much larger premises, unencumbered by trees or buildings, where I can learn to manœuvre my machine. I am only able to devote a small fraction of my time to these experiments, as I am and have been for many years, the managing director of a great English company, but I have put in all the time that I had to spare for the last five years, and the experiments have led me to believe that the flight of man is possible even with a steam engine and boiler. I would, however, advise the young engineers who may read this paper, if they wish to do something to advance the science of aviation, to turn their thoughts in the direction of a petroleum motor. These motors have been greatly improved of late years, and I believe it is the petroleum motor that we must look to in the future as being the engine which will drive our flying machines. Petroleum is cheap and abundant; it may be obtained in any quarter of the globe, and no other substance that we can obtain on a commercial scale contains such an enormous quantity of latent energy.

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